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NOTES

ON THE

TREATMENT OF MERCURY

IN

NORTH CALIFORNIA.

BY

T. EGLESTON, PH. D.,

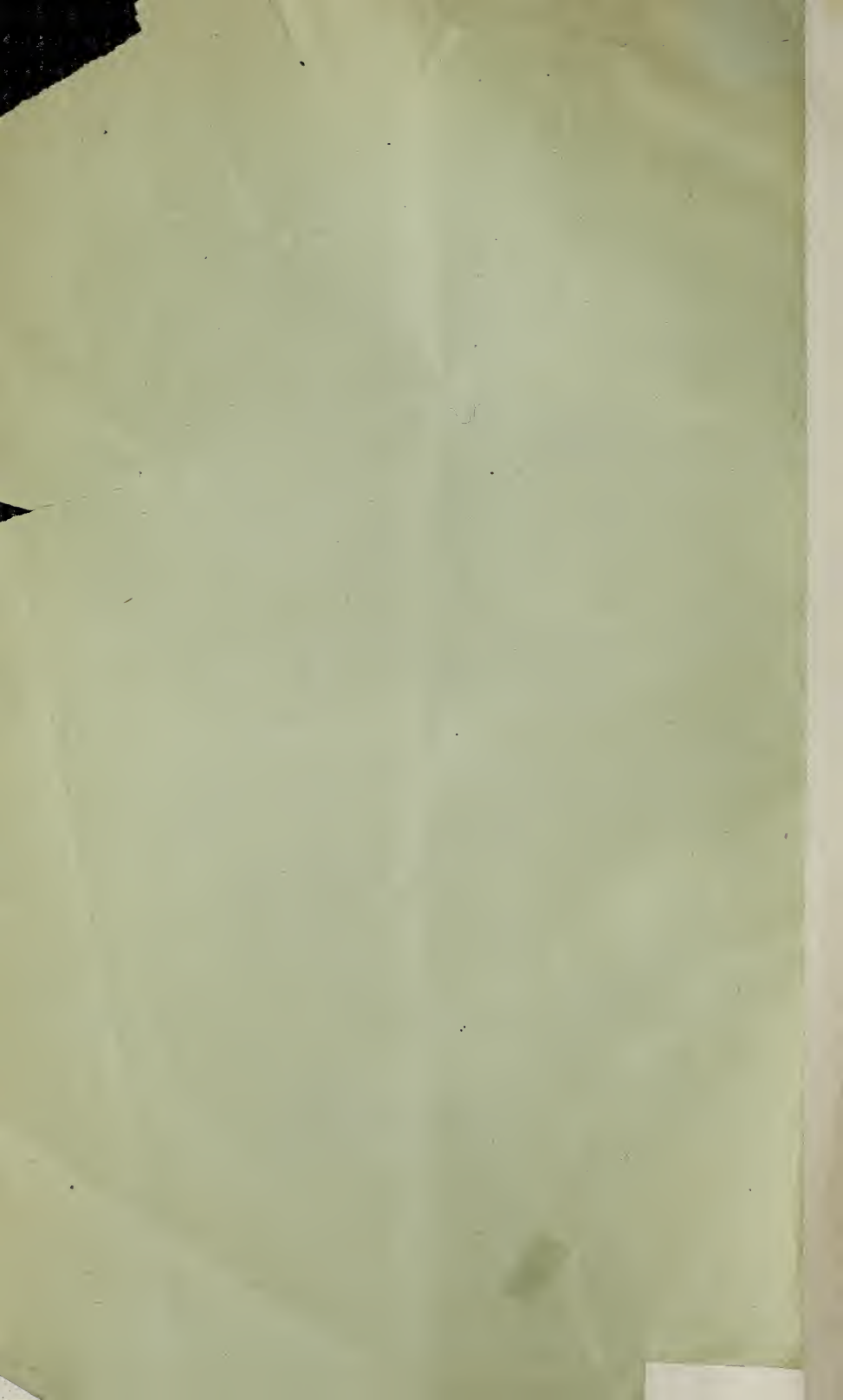
COLUMBIA SCHOOL OF MINES, NEW YORK CITY.

[FROM VOL. III TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

PHILADELPHIA:

SHERMAN & CO., PRINTERS.

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NOTES ON THE TREATMENT

OF

MERCURY IN NORTH CALIFORNIA.

THE ores of mercury of North California are composed of metallic mercury and cinnabar. They are found in serpentine, and are very often associated with chalcedony, in masses more or less irregular, often concentrated enough, however, to furnish ores yielding from three to ten per cent., and sometimes richer. This deposit makes its appearance in Vallejo where it has been worked. North of here the mines are more developed. Most of the quicksilver mines, however, are situated in Sonoma and Napa Counties. On its outcrop the serpentine rocks have become decomposed, and have often been washed away to a considerable depth, so that in many cases in their neighborhood, what is apparently nothing but ordinary dirt, will frequently contain from two to three per cent. of metallic mercury, with but a trace of cinnabar, in which case, as at the Sonoma mine, it is made up into adobes and distilled. Such material does not require to be mixed with dirt to be made into adobes. Very often, also, the outcrop of the rock, where it is not decomposed, is filled with metallic mercury, so that by striking a pick into it, as at the Rattlesnake mine, a pound or more of mercury at a time will sometimes spurt out. Such rock as this is found in several localities in every stage of impregnation, and usually makes very rich ore. There is generally, however, very little of it, and it is found only in the first workings; the ore in depth is always cinnabar. At the Rattlesnake mine near Pine Flat, where large quantities of metallic mercury are found, the rock contains so much petroleum that it has been necessary to make special arrangements to burn the carbides of hydrogen, since the distillation of the petroleum causes an extra quantity of poor soot to be formed in the condensation-chambers. At the Geysers the ore is associated with large quantities of sulphur and gypsum, so that in a hand specimen there is often more sulphur than cinnabar, which is

a serious impediment to working, especially for the modern style of furnace with iron condensers, and causes so much soot to be formed that it has been known to penetrate as far as the blower, and to so completely clog it as to prevent its revolution.

The ore coming from the mine is more or less hand-picked. In one or two cases attempts have been made to treat the poorest, and especially the very fine ores, mechanically as at the California works. The apparatus used for the purpose is very rude, and the treatment does not seem to be very successful, as there is visibly a considerable loss in the tailings.

Usually the fine ore is not concentrated; it is taken as it comes from the mine, mixed with dirt and made up into adobes, which have no regular size or weight, and treated in the furnace.

The processes by which the ore is treated are, first, the process by precipitation; second, by roasting. The precipitation is done in retorts with lime, and consists of oxidizing the sulphur by means of an excess of air, and so producing sulphate of lime and free mercury. The roasting is done either in retorts, or in other furnaces which are not continuous, and in several styles of continuous furnaces. The reaction consists in volatilizing the sulphur and oxidizing it so as to produce free mercury and sulphuric acid, which, with the moisture of the fuel and ore is condensed and allowed to run to waste. The furnaces which are not continuous are a modification of the old Idria furnace, which is used at Knoxville and at New Almaden in South California. Those which are continuous are the Luckhart, which is used at Sonoma, and which was being built at the Rattlesnake mine and elsewhere; and the Knox furnace, which is in very successful operation at the Redington, Manhattan, and the California mines, and elsewhere. There are a number of other varieties of furnaces, none of which, however, I saw. To these processes should be added the process of distillation, if the metallic mercury of the outcrops were found in sufficient quantities to warrant the ore being treated alone. This, however, has never been the case, and the small quantities that are found are charged in the furnace with the other ores, either as rock ore or as adobes. Very little effort is made to sort the ore, and this generally consists in a rough attempt at hand-picking. No assays of any kind are made. The furnace manager, or miner, judges by the eye that the ore contains one, two, three, ten, or twenty-five per cent., as the case may be, and hence there is little faith to be placed in the statement of many of the advocates of different kinds of furnaces, that their furnace yields such and such a percentage of the assay value.

The mercury produced is put up in iron flasks, which contain $76\frac{1}{2}$ lbs. each, with an iron screw for a cork, and shipped. Irregular flasks, as they are called, contain less or more.

METHOD OF DISTILLATION.

AMERICAN MINE.

At the American Mine, near Pine Flat, all the ore is crushed fine in an ordinary California stamp-mill, with a battery of ten stamps, which is run at a high velocity. It is then mixed with lime, and treated in retorts. The average yield of the ore is said to be two per cent.

There are twelve retorts 9 feet long, 2 feet wide, and 18 inches high in the middle. They are made of cast iron, and are D-shaped like the ordinary gas retort, and are arranged in benches of three, the centre one being the highest, so that there are four fireplaces to the twelve retorts. The charge consists of 150 lbs. of crushed ore, to which ten per cent. of quicklime is added. This charge is introduced into the muffle in an iron spoon 6 feet long, 9 inches wide, and 6 inches deep. This is carried by three men, one taking the end, which has an iron handle 2 feet long, with a crossbar of wood of the same length. The middle is supported on an iron bar, curved in the middle to fit the shape of the spoon, with handles projecting 18 inches from the sides, and is carried by two men. This spoon is introduced into the muffle and shoved to its end. It is drawn out by short jerks, so as to leave the charge in the retort. The doors of the retort are then fastened by means of thumb-screws, and luted with wood ashes, and fired during four hours, when the charge is withdrawn. Not over 500 lbs. per retort is treated in twelve hours.

The condensation pipes are in the back of the retort. A pipe, about 18 inches long, connects each retort with a vertical pipe about 5 feet long, which connects with a horizontal pipe 6 inches in diameter, placed in a water-tank at a lower level than the front of the furnace, and which receives the pipes of all the retorts. Every six retorts are so arranged that they discharge their condensed mercury through a siphon pipe.

The soot is treated with lime as is usual.

These works are new and carefully built. It is surprising to see works upon which no expense seems to have been spared, apparently put up to treat such very small quantities at a time of very lean ore by such a system; not even the *possible* economy of the retort system seems to have been taken into account. There did not seem to be sufficient care taken with the condensation apparatus, for the air

for some distance from the works was filled with mercurial vapors; and though the workmen wore wet sponges over their mouths and noses, most of them were more or less salivated. I did not visit the mines; but any mine which would justify such carefully erected works with stamp-mills, would certainly justify the erection of other and less wasteful furnaces.

METHOD OF ROASTING.

The method by roasting is the one which is the most extensively used, and all the different varieties of furnaces are adapted to it. Those most in use are retorts, and the modified Idria furnace of the non-continuous varieties, the Luckhart and the Knox furnace of the continuous ones.

NON-CONTINUOUS FURNACES.

Missouri Mine.

At the Missouri mine, near Pine Flat, the average yield of the ore is from one-half to 2 per cent. of mercury. The cinnabar is irregularly scattered through a chalcedony found in very irregular masses in serpentine; the large pieces are crushed in a Blake's crusher to about 1 cubic inch in size. There are two benches of retorts, one containing two retorts and holding 250 pounds of charge at a time, and the other containing three retorts and holding 350 pounds, so that the small retorts treat 1000 and the large ones 2100 pounds in twenty-four hours. The large retorts have been in use but a short time, and have consequently produced but little. The retorts are D-shaped, and are here 9 feet long, 12 inches high, and 18 inches wide on the bottom; they are charged every twelve hours by means of a shovel. At the Lost Ledge mine the same company have three retorts which are only five feet in length, and have a capacity of 500 pounds, or 160 pounds each; they are charged every four hours, and consequently treat 3000 pounds of ore in twenty-four hours. It takes three-quarters of an hour at the Missouri mine to discharge and charge the large retorts, and half an hour for the small ones, so that, as there is not much difference in the wear and tear, the large size retorts are the most advantageous. They are never filled full, as there would be danger that the pressure of the discharging vapors might force an exit through the luted joints.

When the furnace is ready to be discharged the men cover their mouths and noses with wet sponges, tied on with bandages, and then remove the cover of the retorts. When they are about to be removed a little fan placed on the condensing pipes is set in motion to cause an aspiration through the retorts, so that no mercurial fumes

escape. When the fumes cease to be dense the charge is drawn out of the retort with long hoes on to the floor in front of the furnace. The discharged ore is at a cherry-red heat, and, as it is not entirely free from mercury, a considerable quantity of fumes are given off so that the precaution of using the bandage over the mouth and nose is indispensable. After the ore has all been raked out, it is carried as quickly as possible a short distance from the furnace and extinguished with water, a new charge being put in in the meantime. This is an exceedingly bad system, as the workmen are constantly exposed to fumes, more especially when water is scarce, since small quantities at a time thrown on the very hot ore seems to increase the quantity of fumes. The men, however, seem to know this, and take the necessary precautions, as none of them were salivated. The product of the small retorts varies from $3\frac{1}{2}$ to 70 pounds of mercury in twenty-four hours. The large ones yield from 10 to 100 pounds.

As the two benches of retorts are at some distance, each bench requires one man per shift of twelve hours, who is paid \$3.75 a day. They burn $3\frac{1}{2}$ cords of wood in twenty-four hours. Wood costs \$6 per cord, and labor \$64 per month with board. Each retort is connected by a short joint, with a horizontal pipe leading to the condenser, which must be large enough to insure of its not being clogged by the soot. This pipe is of cast iron, and is 30 feet long and 6 inches in diameter. The pipes leading from the retorts, in the latest and best construction, come from the back, where there is plenty of room and they are not in the way, so that they can be large. Formerly they were made to come from the front, where they were in the way of the workmen, and were constantly in danger of being damaged by the charge lying against them as it was drawn from the furnace.

The condensing apparatus consists of two cast-iron boxes 3 feet by 2, and 2 feet high, turned down into cast-iron tanks, with inclined bottoms, which are covered with water. From the bottom of these tanks a wrought-iron pipe, curved in the shape of an S, is placed, with the arms sufficiently long to counterbalance the pressure of the water, so that the mercury flows from it continuously. The mercury commences to flow two and one-half hours after the charge is put in. Between the two cast-iron boxes, which are connected with each other, and on the main pipe, a small fan-blower is placed, and is made to suck out the vapors from the retorts, or when the condenser is to be cleaned into an exterior pipe. The fan is inclosed in a box 18 inches square, into which there is an opening 1 foot in diameter, closed with a hydraulic packing. The pipes and condensers are cleaned once a week.

In the small furnace 140 pounds of soot and mercury together are collected; this is put into a sheet-iron pan, 8 feet long, 3 feet wide, 6 inches deep, inclined about 25° , which is not fixed, but is moved from place to place as convenience may require. The soot is placed at its upper end, and is worked with a hoe for a quarter of an hour, to separate the free mercury. Three to five pounds of unslacked lime without water are then stirred into it. As the soot is already damp, the lime soon commences to slack; it is left until it slacks entirely. No one goes near it for one-half or three-quarters of an hour, on account of the vapors arising from it. It is then worked with a hoe for three hours. About one barrel of lime, which costs \$3 the barrel, is used per week for treating the soot. The mercury as it is collected runs into the lower part of the pan, and is taken out with a ladle and put into flasks. The residue, which has twice the bulk which the soot originally had, is added to the next charge of the retorts, in addition to the charge of ore. Such a charge will produce about 10 pounds more of mercury than usual. From 140 pounds of soot, 120 pounds of mercury are obtained directly, and about 10 pounds more from soot charged in the furnace. The large furnaces were run 10 days; 200 pounds were taken from the first condensers and pipes, and from 12 to 14 out of the second condenser. When there is only a small amount of soot to be treated, a small cast-iron sink 3 feet by 18 inches is used, the drain-hole being placed over an enamelled iron vessel 1 foot in diameter, and 6 inches deep. This vessel is used because ordinary kitchen utensils answer perfectly well, and can be had much cheaper than special apparatus, which would work no better.

The expenses are for twenty-four hours:

2 men at the retorts, ...	\$6.50
$3\frac{1}{2}$ cords of wood, at \$6, ...	21 00
Lime for soot, ...	50
Crushing the ore two days, at \$1.25, ...	2.50

There does not seem to be any real economy in using this retort system. The yield is not greater, nor is the cost of repairs and running less, while the risk of salivation is greater. There is certainly an economy of first installation, and this seems to be the only reason why such furnaces are used. With the high prices of quicksilver which have ruled during 1873 and most of 1874, every place where ores could be found has been worked, and as all the deposits are irregular and uncertain, the owners of such mines have not felt themselves justified in going to any greater expense. I saw no well-developed property, nor any property which appeared to have any

future, which was worked with retorts, except in a few instances, where the retorts were put up to have a yield while other furnaces were being erected on the property developed, or where the mines were evidently being worked with too small a capital.

MODIFIED IDRIA FURNACE.

Redington Works.

As an example of non-continuous working with shaft furnaces, I have selected the practice of the Redington mine, with the old Idria furnace, which is by far the largest mercury works in North California. But as everything relating to this variety of furnace, which is destined in a few years to disappear altogether, is of interest, I have added some details relating to the New Almaden furnace of the same type, which I visited shortly after, although they are south of San Francisco. Great attention is being paid to the question of condensation, which is, perhaps, even more important than that of the furnace. The two questions are, however, intimately connected, and are engaging the most serious study of all persons interested in the metallurgy of mercury.

At Knoxville, the Redington Quicksilver Company treat the ores from the Redington mine, which they own, in both the modified Idria furnaces, of which they have two, and also in the Knox furnaces, of which there are two working, and two in the course of construction; besides these, two others are to be built. The furnaces are situated at the mines and within a few feet of the ore shaft. The mine produces 700 to 800 tons of cinnabar per week. The ore occurs in a sand-rock, in serpentine. Much pure cinnabar is found, and a considerable quantity of high grade ore, but the average yield of the whole mine is about 3 per cent. Metacinnabarite is found in considerable quantities in these mines. Epsomite, resulting from the decomposition of the serpentine, also occurs here in very large quantities, in acicular crystals over a foot long. The ore is largely associated with pyrites. About one-tenth of the ore comes from the open cut made in the side of the hill. From the mine the ore is thrown upon screens placed one over the other; the upper screen is made of round iron bars $1\frac{1}{2}$ inches in diameter, placed 2 inches apart at the top, and $2\frac{1}{4}$ at the bottom. The screen itself is 5 feet wide at the top, 5 feet 6 inches at the bottom, and is 8 feet long. Whatever passes over this screen only, is hand-picked. What passes through falls upon strong iron-wire screen of $\frac{3}{4}$ -inch mesh. What goes over the second screen goes directly to the furnace, and is charged with the hand-picked ore; what passes through is treated as fine ore; all

the large pieces are broken by hand. Before the Knox furnace was introduced, the ore was dressed by hand up to 5 per cent.

All the fine ore is mixed with dirt and made into adobes, which are sun-dried and stored, for use in the modified Idria furnaces exclusively. There is no generally adopted size for the adobes. They are made in roughly constructed wooden frames, made by the workmen, which wear out rapidly. The usual sizes are $9 \times 4 \times 4$ inches. When dry such adobes weigh 12 pounds. They are sometimes made $12 \times 5 \times 5$ inches, which is a very large size. Such adobes weigh 18 pounds. The smaller size is the one most generally used. Seven men, at \$2 per day, can make 6000 adobes. Each man can mould one thousand, but the six men require one man to loosen and moisten the dirt, and to mix the ore with it. Making the adobes costs, therefore, \$2.33 the thousand. The cost of the adobes delivered at the furnace, ready for charging, including making, carting, and storing, is \$5 the thousand.

The modified Idria furnaces (Plate VIII, Fig. 1) are built one on each side of the condensers, which are at right angles to them. Each of these furnaces is capable of treating 100 tons of ore with 4000 to 5000 adobes per week. They are built of a porous sandstone, which is found a short distance from the works. Each furnace has a double fireplace, B, 20 inches in width, 17 feet long, and 15 feet high, from the spring of the arch of the fireplace. The total inside height of the fireplace compartment is 20 feet. It has on the ore-chamber side a brick screen pierced with fourteen openings, the size of one brick, and two bricks apart, across the furnace, and fourteen openings in height, also two bricks apart. The fireplace wall has been repaired once in seven years. It is made of red brick, and is glazed by the heat. The ore chamber, C, is 13 feet by 10, and 20 feet high. Its walls are 4 feet thick. There are two ore discharge openings, 32 by 20 inches, on each side, at the bottom, which are four feet above the ground. The car for discharging the furnace runs under a swinging apron of cast iron, and the ore which has been treated is raked out over it. The fireplace and condenser wall are each mere screens of brickwork filled with holes, which are the starting-points of the flues, made in the charge. As the condenser side is constantly exposed to the acid vapors, it is the one most rapidly worn. It has been renewed twice in five years. It is now strengthened with an abutment. From constant use the inside walls round the ore-chamber have become worn away, making its present size somewhat larger than it originally was. Beyond the ore-chamber each furnace has two sandstone condensers, D, which are 4 feet wide, 13 feet long, and 20 feet high,

in which very little material ever collects, never more than two flasks of mercury a week.

In the drawing, Fig. 1, Plate VIII, these furnace condensers are connected with the main condensing chambers, A, by the flues, E, which are supported upon arches, and which enter the top of the first chamber of the main condenser, A. The length of the flue between the furnace and the main condenser is 8 feet, and the furnaces are so arranged that each one may work independently into the condenser, the connection being cut off at will. The total length of each furnace, including the fireplace, ore-chamber, and two condensing chambers, is 36 feet, its total width is 17 feet, total outside height 24 feet. The main condensers, A, consist of a series of twelve chambers, each of which is 4 feet wide, 20 feet long, and 20 feet high on the inside, contained in a structure at right angles to the furnaces, and which is common to both of them. Each one of these compartments has an iron door on each side on a level with the bottom of the chamber. The inside walls of the condensers are 1 foot thick, the outside 18 inches. They are braced on the outside with wooden beams 8 x 10 inches, which are tied with $\frac{3}{4}$ -inches round iron rods. These rods must be carefully watched, as they are likely to become corroded through, and allow the wall to fall, and thereby cause serious accident.

The walls of these chambers are soon saturated with mercury, and become soft from the effects of the acid vapors. The stones are found corroded for a depth of 6 inches, and some of the interior walls have been corroded entirely through. Whenever they have been repaired with brick, it is found to be quite hard and to resist much better than the stone.

The relation of the condensing surface of the condensers to that of the charging compartment is much too small. The relation of the condensing volume to the volume of the furnace should be at least as 24 to 1. In this furnace, however, it is not more than one-half of that amount. This would make the chambers only large enough for one furnace. That the condensing capacity is not sufficient, is evident, from the fact that metallic mercury has supersaturated the stones, and still exudes in globules from the walls even after repeated cleaning.

The flue leading to the chimney is also built of cut stone, and is 250 feet long. It is oval, 4 feet in the highest diameter inside, with walls 2 feet thick. It lies against the side hill. The chimney is built of stone, with walls 3 feet thick. It is conical, 5 feet in diameter at the base, and 50 feet high.

The furnace is charged by a windlass from above. The ore is let down in iron buckets 3 feet in diameter, and 30 inches high. The adobes are let down in iron cages that hold 150 adobes, which weigh about a ton. This cage is 3 feet by 30 inches, and $2\frac{1}{2}$ feet high. The charging compartment is lined with adobes 2 to 5 thick, piled close, but not crowded. Inside of this the ore is placed in pieces from about the size of an egg to twice the size of the fist, in layers of four, 18 to 24 inches in thickness, then four to five channels the size of an adobe are built of adobes over the ore. Their number depends on the size of the ore, five for fine ore, and four for coarse. These channels start in the opening of the fireplace screen, and end in the opening towards the condensation-chamber. They answer the purpose of flues, and are necessary not only to provide a draft and to allow of the heat coming in contact with the ore, but also to prevent the charge from packing together. The poor soot, or that which has been worked, is charged on top of every layer of ore. A new layer of ore is then put in, and so on, until the chamber is nearly full. A layer of fine ore and poor soot is placed near the top, and this is covered over with clay and straw. The compartments are closed with cast-iron pans, which are filled with water, the joints between the pans and against the masonry being made tight with ashes or cement. These pans are $10\frac{1}{2}$ feet long, $4\frac{1}{2}$ feet wide, 5 inches deep. The cold water flows constantly from an inch pipe into the pan nearest the fireplace. A spout from every pan carries the water to the next pan, so that they are always full. Each pan is provided with two eyes at the sides for their removal when it is necessary to recharge the furnace. One furnace is charged on Monday, and is fired Monday night, and is kept burning until Thursday morning. During this time two cords of wood are burned to each furnace. The sulphur, to a great extent, answers for fuel, for there is always an excess of sulphur in the shape of pyrites in the ore. The other furnace is charged on Tuesday, and is fired Tuesday evening, and kept burning until Friday. One furnace will thus be cooling on Saturday and Sunday, and the other on Sunday and Monday. A little mercury commences to run in D on Tuesday, and in the 1st, 2d, and 3d compartments of the main condenser. It runs most freely Wednesday and Thursday. By Thursday the mercury condenses quite in the end of the condenser, but only in very small quantities; 150, sometimes 200, flasks are collected from both furnaces during the week; most of it comes from the 5th and 6th condensers. On Wednesday it commences in the 5th and 6th, and runs from here con-

tinually until the furnace is discharged. The most of the mercury is obtained when the furnace is cooling down. When the draft is good and the ore moderately rich the yield will not be less than 200 flasks a week.

The bottoms of the condensing-chambers were originally built inclined toward the centre, as is shown in the lower part, Fig. 2, with the intention of having all the mercury in all the condensers run out through a common opening made for the purpose, but the openings in the partition walls of the condensing-chambers very soon became clogged, and so much mercury was absorbed in the masonry that this was shortly abandoned. The present disposition is iron pans sloping from the centre toward the outside, as is shown in the upper part, Fig. 2, which are placed 3 feet above the furnace bottom of the old construction, which has not been altered, so that there is a space of considerable size under the bottom of the pans. The pans are made in three pieces, which overlap each other. This is especially necessary, as when the walls get old and fall, the whole pan would then be liable to be broken. Tiles placed upon the top of the pans to protect them have been used with good effect. The castings with this protection have lasted already four years, and are seemingly perfect. The cast iron without the tiles lasts only two years, at which time it is corroded by the sulphuric acid which condenses from the furnace.

On Saturday the iron doors at the bottom of the condensation-chambers are taken off, and a workman with a long hoe collects the soot on the pan and that from the walls about two feet above the bottom of the pan; what is higher up on the wall is left to collect there until it falls of its own weight. 75 to 100 bushels of soot are collected in buckets every week from the bottom of the condensing-chambers, which yields from 5 to 20 flasks of mercury. This soot is a mechanical mixture composed of ordinary soot condensed from the smoke of the fuel, ashes, fine dust and dirt carried over from the ore, volatilized cinnabar, and sublimated mercury in very fine globules. It is usually taken from the condenser damp, owing to the condensation of steam from the moisture in the fuel and ore, and the acid vapors. This soot is removed in buckets, 14 inches in diameter at the bottom, 30 at the top, and 33 inches high. Two such buckets filled one foot high are taken from each side of the condenser. Sometimes as many as eight, and sometimes not as many are taken. It takes two men two days to clean out and work the soot from all the five condensers in an ordinary working of the furnace. The amount collected is very variable. When, for any reason, such

as a stoppage for repairs, the furnace cools, a large quantity of soot becomes detached at the time the furnace is lit. The amount of mercury collected from the soot varies from 5 to 20 flasks a week. The flue leading to the chimney is cleaned once in two or three weeks; about one bushel of soot is taken from it. This is not kept separate, but is mixed with that taken from the condensers.

It takes ten men one day to charge each furnace, and six men one day to discharge it. The six men are paid about \$35 per month and board, making about \$1.90 a day. There is a fireman and one man to clean and repair the flasks and to fill them. They work during the day only. Each shift of twelve hours has its own foreman. This does not include the men working up the soot. When the draft is not good a fire is placed at the foot of the chimney, which is fifty feet high, to increase the draft. The draft depends for the most part upon the way the furnace has been charged, but is sometimes due to the direction of the wind. This draft furnace is oftenest used when the furnace has been allowed to get cool. Not a cord of wood per month is required for this purpose. In winter, fall, and spring there is no trace of mercury in the flue, but when the weather is hot it collects inside, near the top of the chimney, which is provided with a ladder in order to make any observations on the escape of gases at the top which may be desirable. When the furnace is out of repair in very hot summer weather, it is apparent that some mercury escapes. The joints of the furnace are made so tight that no accident arises from salivation except through the carelessness of the men. As soon as the workmen experience any sensitiveness about the mouth they are instructed to go to the office, and are there furnished with a mouth-wash, consisting of 2 parts of cinchona, 1 part tincture of myrrh, and 3 parts water, but no case of real salivation except from the carelessness of the men, has occurred in a great many years.

Twice in a year a general clean-up is made. This is done by putting iron pipes, 24 inches in diameter, in compartment D, and three in the flues leading to the chimneys, both to hasten the cooling and ventilate them while they are being cleaned. The walls of the condensers are cleaned by scraping. On account of the dust arising from the falling soot, it is necessary, when this work is done, for the men to wear a wet sponge over the mouth and nose, which is covered with a thin cloth tied behind the head. At this work, the men relieve each other every fifteen minutes. After scraping, the walls are thoroughly washed. It takes eight men two days to scrape and wash the walls, flues and condensers. The soot so detached

contains a large amount of mercury. From such a general clean-up as many as one hundred flasks have been collected. The soot in the first condenser is often 6 inches thick in concretions. It is here hard and solid, but in the other condensers it is soft and light. The light soot upon the walls is of very variable thickness, but is rarely less than 1 to 2 inches thick. It sometimes reaches as high as 6 inches after a long run without cleaning. When there is very rich soot it may often be as thick as 6 inches on the bottom of the iron pan. The soot is richest in the fourth, fifth, and sixth condensers, but it is always very unevenly distributed. In all the compartments in the space below the iron pans a hard concrete, consisting of hardened soot and mercury in globules, is found.

The furnaces with the condensers cost originally between \$100,000 and \$125,000; they have been built eight years, and have been repaired three times, parts of six partition walls having falling down at the flue end. At the furnace end the wall is good. The walls after having been scraped and washed every day for a month still showed mercury in globules all over them, a few hours after they became exposed to the heat of the sun. All the stone taken out of the condensation-chambers during repairs is carefully preserved and is treated as very rich ore.

The first time that the furnace was charged the ore was picked. At the top of the charge, over the rich ore, 6 to 7 feet of rich soot were put in, but the heat did not reach it. The charge being unusually rich, should have yielded five hundred flasks of mercury, but all but nine flasks of it were absorbed by the walls.

This furnace has been definitely abandoned at Knoxville. The masonry has been altered into Livermore's inclined continuous furnace, which is adapted to treat fine ores, and since its introduction, in the earlier part of 1875, no adobes are made. The cost of altering the furnace was only \$1200.

Average cost per week of reducing 1 ton of ore in the modified Idria furnace, at the Redington mine, furnaces Nos. 1 and 2, in 1874:

5½ cords of wood at \$5, ...	\$27.50
36 days, furnaceman, fireman and his assistant, ...	86.00
20 days, laborers charging furnace, ...	38.60
12 days, laborers discharging furnace, ...	23.15
8 days, laborers working soot, ...	14.55
8 days, fireman, ...	14.55
9000 adobes at \$5 per thousand, ...	45.00
Total charge of 200 tons cost, ...	\$249.35
Average cost per ton for reduction, ...	\$1.25

New Almaden Works.

At New Almaden, the Quicksilver Mining Company have six furnaces of the modified Idria type, built of brick, which produced in the year 1874, 11,042 flasks of $76\frac{1}{2}$ pounds each, or 920 flasks per month. Four of these have a capacity of 50 tons, one a capacity of 70, and one 100 tons of ore a week. They run a week, so that each furnace makes four charges a month. Each furnace has from sixteen to twenty-two brick condensing-chambers, the numbers varying with its ore capacity. The bottom of the chambers inclines from the centre toward the doors. The floor is built of brick, and is covered with cement. Beside the brick condensers, each furnace has four to five wooden condensers, which are 26 feet long, 14 feet wide, 20 feet high, divided into six compartments of equal size. As the result of the addition of these wooden chambers, one of the flues, which formerly yielded in the general clean-up from 60 to 100 flasks of mercury, yielded in the year 1873 only two flasks, and the largest part of this was found near the outlet from the condensers, and no signs of metal were found further on.

It is the present intention to cut up the blocks of brick condensers by taking down the outside wall of one or more compartments, and making the dividing walls the exterior walls of the new structure. The former condensers will thus be divided into three or more separate buildings. A much larger radiating surface being exposed in this way, it is expected that the condensation will be much more perfect. Adobes $10 \times 4\frac{1}{2} \times 4\frac{1}{2}$ inches in size, made of the fine ore mixed with dirt, are placed over the floor of the ore-chamber, one adobe thick the entire height of the sides; ore is then put $2\frac{1}{2}$ to 3 feet in thickness, then a layer of adobes, in which five flues from one side to the other of the furnace are made, and then ore, and so on to the top. The top is covered with a layer of adobes, and then a layer of straw 2 or 3 inches thick, and then ordinary clay and mud, to make it even with the top, and over this ashes. Any cracks that may occur are filled in with ashes. When the furnace is filled, one-third of the charge will be adobes; sometimes the furnace is run on adobes alone. It takes six men one day to charge the furnace. It takes one man part of twelve hours to keep up the fire. It takes four men one day to discharge it. The charging is done by the company, as it must be carefully done, but the discharging, as it requires no supervision, is done by contract. The fire is kept up for ninety-six hours, and during this time 18 cords of wood are burned for 100

tons of ore. The wood costs from four to six dollars a cord. The ore is discharged twelve hours after the fire is drawn; twenty-four hours afterwards the soot is taken out.

The mercury commences to condense fourteen to sixteen hours after the furnace is lit. If the ore is very rich it sometimes commences to condense in eight hours. It appears first in condenser No. 1. In Nos. 1, 2, 3, 4, and 5, it runs for ten hours; after this it runs in Nos. 3, 4, 5, 6, 7. It appears in No. 7 on the second day, after which it ceases to run in the first four condensers, but continues to run in all the others. The greater part collects in Nos. 9, 10, and 11. Before the fire is drawn, half of all the mercury is condensed, which is in about forty hours, gradually diminishing until it ceases to condense. A small amount of mercury still runs, however, the flow being kept up by the dripping from the walls. From the bottom of each of the condensers there are small pipes leading into an outside trough, to allow any mercury that forms to run immediately into the gutter, from which it is discharged into the reception basin.

The iron doors which close the entrance to the brick condensers have been given up, except for the first four or five chambers, and are now replaced by ordinary glass window-frames 3 x 3 feet, with six panes of glass. It is found that there is a material difference in the condensation since they have been adopted. The condensers made of wood and glass, which were patented in May, 1874, are in successful operation here. They are certainly much cheaper, and it would seem a much better condenser, and less likely to get out of repair than the iron ones used elsewhere. This kind of condenser requires no water, and is, therefore, applicable everywhere. The want of water in many places in California is often a serious drawback to the working of the ores. Four such condensers are at work at New Almaden. Each one has a volume of 2640 cubic feet, and 1196 square feet of condensing surface, or altogether 10,560 cubic feet volume, and 4784 square feet of surface. They have cost only \$1500, which is the smallest cost for any such amount of condensing surface known. If they work as well as they promise they will replace at least half of the iron or brick condensers.

The soot is collected in the same way as at Knoxville. That collected from four charges gave 18 flasks of mercury. The same four charges produced 474 flasks. The soot condenses in all the condensers from No. 4 on; the most of it collects in 10, 12, and 14, or about in the middle. On an average about a lime-barrelful per

week is collected from each condenser. One man does the whole cleaning up.

The soot was formerly placed on an inclined plane, and stirred and slightly rubbed with a wooden hoe. A certain quantity of quicksilver separated and ran out into a vessel prepared for it, but left a very large quantity still remaining in the soot, which was afterwards treated with lime. This method, which is in general use and takes a great deal of time, has been given up here. The soot is now put into a hemispherical boiler about 3 feet in diameter; it is mixed with boiling water from a vertical boiler, used for this purpose only. About half of the bulk of soot is added in wood-ashes, and the whole thoroughly stirred with an iron hoe for three-quarters of an hour, when the separation is complete. It is then allowed to remain an hour and settle, and during this time another boiler is worked. The mercury collects in the bottom of the vessel, and flows out of a siphon-shaped pipe, so that only the pure mercury is discharged. The water is drawn off afterwards, and the soot remaining behind is thrown into a heap, and when dry is placed upon the top of the furnace near the flue where the flame passes, as it still contains some sulphur. It is claimed that all the mercury in the soot is separated in this way and with much less labor than by the former method. This process was patented October 4th, 1873.

It takes one man, working ten hours, four to five days to work the soot of six furnaces.

The fuel used here is wood, or ordinary charcoal made from oak, or a mixture of charcoal and coke. It requires 75 lbs. of coke and charcoal mixed to 3000 lbs. of ore and adobes, or equal quantities in bulk.

This furnace, as used here and at Knoxville, must be considered as a very great improvement on the old Idria furnaces, as there are no arches in the ore-chamber which are likely to break down without warning.

The method of charging large and small ores and arranging air-channels by means of adobes prevents the charge from packing, and gives all the space which is required for the circulation of the air and heat, and allows of using a poorer ore than could be otherwise used. The labor of making the adobes, which is, however, only \$5 the thousand, must be regarded as a necessary expense, as the furnace could not be run without them; as the expense of making the air-channels of large pieces of ore would be too great, and there would be no certainty that they would last if so made. The adobes, however, do not change their form, and the air-channels once made

remain as they were made in the charge. The making of adobes is, however, one of the expenses to be avoided in the furnace of the future, and the most careful attention now being given to the construction of furnaces which will allow of the fine ore being treated as it comes from the screens. Although this furnace, with its expensive, cumbersome method of condensation, is a great improvement on the old Idria furnace, it is destined to disappear, and in a few years will probably be cited as one of the curiosities of metallurgical history.

CONTINUOUS FURNACES.

The continuous furnaces in use are all of them shaft furnaces, which do not differ essentially in the principles of their construction, though there are wide differences of detail, which are more or less essential. The California practice is essentially different from that of other countries, in that all of these furnaces are provided with fans placed beyond the condensing apparatus, which not only do away with the necessity of high chimneys, but give such an absolute control of the draft that there is no fear of the fumes escaping. The draft is always toward the interior of the furnace, so that even if an aperture in the furnace or the condensing apparatus should remain open, no fumes escape, and consequently cases of salivation are very rare. As the velocity of the fan can always be changed, the draft can be regulated at will to suit either the working of the furnace, or the irregularities of the weather. The furnace is of less consequence than the condensation apparatus, though its aim should always be to extract the metal at the lowest possible temperature, and to require the least possible preparation of the ore. It is consequently on the condensation apparatus rather than on the furnace that the greatest number of experiments have been made; providing that the furnaces are continuous, the one which has the best condensation apparatus will be the best.

There are a number of these furnaces used in California, all of which I believe are patented. I saw, however, but two of them, the Luckhart and the Knox, working.

LUCKHART FURNACE.

The Luckhart furnace is, in all respects, similar to the Swedish furnace for roasting iron ores. It consists of a shaft with a fire-box, with openings in the two sides only, which goes through the furnace from one side to the other. It is covered with a cast-iron roof slanting from the centre towards both sides of the furnace, so that the

charge is divided as it passes down, and the heat is also divided as it passes up. The sides of the furnace are pierced with holes to observe what is passing in its interior, and to watch the progress of the charge. The discharge door is sufficiently far below the grate to insure the ore remaining long enough in the furnace to have all of its volatile contents distilled, and to be sufficiently cool to be discharged with perfect safety into an open wagon at the bottom. By this system, which is common to all the continuous furnaces, the inconveniences arising from the discharge of hot ore not entirely worked are avoided.

The Luckhart furnace used at the Sonoma mine, is capable of treating 15 to 18 tons of ore and adobes a day. The richest ore treated has not contained over 10 per cent. The serpentine containing the mercury crops out near the furnace, and is very much decomposed. The rock is soft and crumbly, and where it is exposed to the weather, its débris have been washed away so that the soil for some distance from the outcrop is composed of its detritus, more or less mixed with free mercury, and a very little undecomposed cinnabar. Where the rock has been mined so as to reach the undecomposed parts of it, it is found to contain in the upper portions more or less free mercury mixed with the cinnabar, but nine-tenths of all the ore treated consists of dirt taken from the surface of the ground, which is made into adobes by Chinamen. The adobes contain from one-quarter to one-half per cent. The rock does not contain more than one and a half per cent. The adobes are made by mixing the earth with water to a thick paste, and then putting it into wooden moulds 5 by $4\frac{1}{2}$ inches, and 4 inches high. The thick mud is simply placed in a frame containing 8 of these moulds, patted with a shovel, the wooden frame drawn up, and the adobes left to dry in the sun; it takes about two days to dry them. When ready for use, they weigh about eight pounds each, and are a little larger than an ordinary brick. One Chinaman can make a thousand in a day. The men are paid \$1.25, and find themselves. It takes two Chinamen, at \$1.25, to pick as much dirt as six men can use for making adobes.

The furnace is charged by means of a circular hopper 22 inches in diameter, and 26 deep; 5 to 6 of these hoppers full make a charge, and 5 such charges make a ton. The hopper is covered over with a hydraulic cover for safety, but even when it is off, the draft is so strong that there is no discharge of mercurial vapors from the top of the furnace, as I assured myself by removing the cover and having the charge withdrawn below the hopper. The furnace consumes one and a half cords of wood a day, which comprises all the fuel

used in the works. The wood is usually oak, and is worth \$3 a cord. About 15 tons of ore a day are treated. Most of the ore is discharged from the bottom of the furnace black, some of the last of a discharge is occasionally red-hot; it is drawn about every hour and a quarter into iron wagons, which hold about half a ton. There are 7 men engaged in making adobes, and there is one Chinaman and one engineer on each shift of twelve hours at the furnace; the Chinaman is paid \$1.50, and finds himself, the engineer is paid \$65 a month. The engineer helps the Chinaman, who draws the charge and dumps it, and charges the furnace and puts in the fuel. In addition to the two helpers, there is one man engaged continually in chopping wood. The total cost of treating the ore is one dollar per ton.

The condensing apparatus consists of three sheet-iron cylinders five feet apart, which are 14 feet high, 6 feet in diameter. The vapors pass from the furnace through a pipe about 20 feet long, in at the top, and out at the bottom of the condenser. A blower is placed just beyond the last condenser, which is three feet in diameter, and makes 100 to 120 revolutions a minute. If there is much fine stuff not made into adobes charged into the furnace, it must be run faster. The engine used is twelve horse-power, but six would answer for a single furnace. Just beyond it is a wooden box, 6 feet high, 12 feet long, and 8 feet wide, into which the blower discharges. This box has a partition in the centre, which goes to within 2 feet of the bottom, to break the current. From this box there is a flue 2 feet square, and 100 feet long, ending in a wooden chimney 20 feet high. Around the top of the condensing cylinders there is a lead pipe 1 inch in diameter, pierced with small holes about 3 inches apart. When there is a plenty of water it is allowed to flow continuously from this pipe, and discharges itself over the outside of the cylinder, thus cooling it. When there is a lack of water it is allowed to flow only over the last condenser. The pipes which connect the cylinders have in their interior a partition about 2 feet long, and on them a considerable amount of soot collects. The bottom of the cylinders incline towards the centre, and from here a pipe leads to an iron kettle on the outside two feet in diameter, which is kept constantly full of water. A large quantity of soot collects on the sides of the condensing apparatus. A little of it constantly falls, and is washed out into the iron basin by the condensed moisture, which is but slightly acid, as there is but little cinnabar in the ore. About one flask of mercury a day is collected from the first two condensers. About one-half of this comes from the second. From the third about a flask a month is collected. The cylinders are pro-

vided with doors, and the furnace is stopped once in three weeks to clean out the soot, which is collected in kettles. About ten flasks of mercury will collect from the soot after some stirring; the rest is put into an iron pan, 9 feet by 3, with a gutter in the centre. The pan is set at an angle of 20° , and gently heated to about 120° F.; it is then mixed with lime or ashes and stirred. The mercury flows readily from it, and about 70 per cent. of its mercury contents is collected in this way. The rest is made into adobes and treated in the furnace.

The more or less acid water which is constantly flowing into the basin outside of the condenser, as it runs off carries away some light mercury and soot. This is conducted to a wooden tank, 12 feet long, 6 feet wide, and 4 feet deep, where it collects and gives a product which contains considerable mercury, which is treated as soot. The soot comes from the basins, the wooden tanks, and sometimes a very little is taken from the blower cylinders. This soot gets poorer as it is further from the furnace. The richest contains 60 per cent. of mercury and the poorest about 3. The product of the works is about 25 to 50 flasks of mercury a month.

The condensation at these works seemed nearly perfect. The manager stated to me that he had exposed a \$20 gold piece for six weeks from the top of the wooden chimney, and that he not only found it there at the end of that time, but entirely unaffected by mercury. There is so little sulphur in the ore that the sheet iron does not seem to have been acted upon to any great extent. With this system of high cylinders with a bottom converging towards the centre, there seems to be but little opportunity for the action of the acid, and with a thick cast-iron bottom there seems to be no reason why it should not answer quite well. It would seem, however, that a few large compartments could not give as good results as a greater number of smaller ones, as a perfect condensation requires a maximum of surface, and does not depend so directly upon volume, though the amount of soot and mercury collected in the wooden box and in the last condenser here seem to show that in this case, at least, owing probably to the very small product of the furnace, the condensation was quite perfect.

KNOX FURNACE.

At Knoxville, beside the Idria furnaces, there were, in August, 1874, at the Redington mine, two Knox furnaces in the course of construction, and two in work, which treated 25 tons of ore each in twenty-four hours, and have been running since January, 1874. During the years 1874 and 1875, two other furnaces have been con-

structed, making six in all, which treat together from 900 to 1000 tons of ore a week. Before the use of these Knox furnaces, and while the modified Idria furnaces were the only ones in use at these works, all the ore had to be dressed up to 5 per cent. Now ore yielding not more than 1 to $1\frac{1}{2}$ per cent., as it comes from the mine, is treated, and Mr. Knox claims that he can treat profitably ore containing not more than $\frac{1}{2}$ per cent. A furnace about to be constructed is to be adapted to treat fine ore exclusively, and it is expected, if this furnace works successfully, to give up making adobes altogether and treat the fine ore here, and if the modified Idria furnaces are still retained, to treat in them only the large and medium-sized ores.

The Knox furnace (Figs. 1, 3, 4, and 5) is a shaft furnace with a fireplace upon the side. The total height of the furnace is 39 feet. The bottom of the fireplace is 17 feet 6 inches from the bottom of the furnace, so that the fire itself is about in the middle of the shaft. The furnace is rectangular in shape. At the top it is 2 feet square; it continues for 2 feet at this size, and then widens out on one side, until at the depth of 4 feet it attains the width of 7 feet. While in the other direction it continues straight for a depth of 10 feet, and then increases gradually until it becomes 7 feet at the fireplace. At this point there are two chambers, Z and Z', Fig. 5, arranged in the masonry, on one side for the fireplace, and on the other, the space for the introduction of the pipe U', which carries off the fumes. At this point, which is 17 feet 6 inches from the top, there commence a series of six retreating arches, which support the masonry of the furnace, four of which retreat 2 feet 6 inches on either side. The two others which are above are much smaller, and reach to within 3 feet of the top of the furnace. At the fireplace the furnace is 7 feet square. The shaft continues to the bottom on the fireplace side of the same size. On the other side it contracts equally upon both sides, so that at the bottom, X Y, where the ore discharges, the width is only 2 feet. The fireplace follows the retreating arches with a width of 36 inches to the top of the second arch, and then diminishes to 30 at the top of the third, and continues so to within 3 feet 6 inches of the top of the furnace. Between each of these arches, on both sides of the furnace, there are openings 6 inches wide, and the whole width of the arch. The aspiration of the blower draws the flame from the fireplace Z to the chamber Z' on the opposite side. The heat of the fireplace is always sufficient to keep it at a dull-red. This construction of the fireplace is far too complicated. These retreating arches are

liable to be worn by the ore, though not very rapidly, but are quite rapidly affected by the fire and the gases. Exactly the same effect might be brought about by the much simpler construction of having the fireplace entirely outside of the furnace. As originally constructed the furnace was quite different. It was 24 x 42 inches at the top, and continued for 2 feet at this size, and then gradually widened by a curve upon one side until at a depth of 7 feet from top it was 7 feet 6 inches wide; it continued to the bottom of the fireplace at this width, and then gradually diminished until it was 2 feet at the discharge. On the other side, at a depth of 2 feet from the top, it widened to 3 feet, and continued at this width to the top of the arch, then followed the retreating arches down to the bottom of the fireplace, where it was 7 feet, and continued at this size to the discharge. There were only three openings between the arches, and it was found that this was insufficient, and the two small arches above were introduced to increase the heat and attack the ore higher up. The fireplace is so arranged that it receives air which enters at the bottom of the furnace and passes round it through a series of channels Y, so that before entering the fireplace, it is heated by the walls of the furnace, and thus effects a small saving in fuel, so that the furnace may be said to be in some respects a hot-air furnace. The masonry of the furnace was formerly made 6 feet thick, and it is now made 8 feet. It is braced by ten large wooden beams, which are held together by iron bolts, and as the furnace is double, are strengthened by three uprights of the same size, also clamped together by bolts which pass entirely through the masonry furnace. By the enlargement of the furnace in the centre the ore as it comes to the point where it is to receive the highest temperature is made suddenly to spread out, so that each particle of it comes in contact with the heat, and is in no danger of fusing. The flames are made to traverse through the six openings between the arches, which are 6 inches in height, to the chamber on the opposite side of the furnace, into which all the fumes are carried by the draft.

The cubic contents of the furnace is calculated in such a way as to be capable of containing about 75 tons of ore, but as only 1 ton of treated ore is drawn from the bottom of the furnace every hour its capacity is 24 tons in twenty-four hours, so that every ton of ore will remain in the furnace at least three days. When, however, the proportion of very fine ore becomes large, or when the ore is wet, the amount that can be treated in twenty-four hours will be reduced to 12 to 16 tons per day. In the case of a large quantity of fine ore it is proposed to remedy this to some extent by charging wood in

small pieces with the ore. This serves to some extent the purpose of keeping the ore open, so as to allow free passage to the heat through the ore, and at the same time creates a source of heat within the charge, so that it will be partially dried, and not pack as it comes down in front of the fireplace. The chamber for the outlet of the vapor is underlaid with a very heavy cast-iron plate, in order to prevent any possible condensation or absorption of the vapor at that point. The pipe U' for the outlet of gas is made of cast iron, is 18 inches in diameter, 16 feet in height, as it enters the condensation-chambers U. It projects 2 feet from the furnace before it turns down; at the elbow there is a man-hole for cleaning the pipe. Just above the outlet pipe a cast-iron door is arranged, so as to observe what is passing in the interior of the furnace on the side. Two of the furnaces were built in one structure on account of economy of constructing and running them. They are charged with $\frac{2}{3}$ to $\frac{3}{4}$ medium, and $\frac{1}{2}$ to $\frac{1}{4}$ of fine ore. Adobes are never used in these furnaces.

The charge is introduced by means of an automatic iron wagon, which contains 18 cubic feet of ore, which is equivalent to about a ton when it is moderately heaped. If the ore is very light, however, the amount contained may be somewhat less than this. When the capacity of the furnace is given in tons, that number of carloads is intended to be expressed. The wagon runs upon rails, and is shoved by the charger to the top of the furnace, where the rim of the wagon first strikes a lever attached to a wire rope, which supports the cover of the furnace, which throws off the cover, then a projection on the body of the wagon throws it to one side. The workman then pulls out a pin in the wagon, which discharges the ore into the furnace. As soon as the ore is discharged the weight of the furnace top and lever drives the car back, when the cover drops and closes the furnace. The weight of the charge holds the wagon in place only long enough for the car to empty itself. The workman shoves the empty car back far enough to be out of the way, covers the furnace top with ashes, and prepares a new charge.

There are fifteen men breaking and sorting the ore, but one man does the whole charging for both furnaces. The fuel used here and at the Manhattan works is the most ordinary oak brush, which is cut by the company and brought one-quarter of a mile. It costs about \$4 a load, which is supposed to be equal to about a cord of good wood. The reason for the use of brushwood is, that during the summer an unlimited supply of it can be had at a short distance from the furnace, both at the Manhattan works and at Knoxville. It is much

more easily cut and carried than wood, and it is a cheap fuel in the summer. As this supply fails in the winter, and teaming is more difficult, wood is used at this season. A sheet-iron trough, 3 feet long and 2 feet square, is hung before the fireplace door. This trough is made to fit the fireplace door, which is counterbalanced and rises vertically. The brush is cut to the length of the trough and is packed into it with a pitchfork, the fire-place door is then raised, and the brush shoved in with the fork. This brush is used green, immediately after cutting. It flames very readily and makes a quick hot fire. It is charged about every half hour. It takes $2\frac{1}{2}$ cords of good wood to do the work of the furnace in twenty-four hours, or two loads of brush, which are considered as weighing one ton. The wood is a mixture of white and live oak, and costs \$5 a cord delivered at the furnace. A ton of the brushwood costs \$5, and is sufficient to treat about 24 tons of ore.

The fireman draws the ore that has been treated and takes care of the furnace. The charge is drawn from a long narrow door X in the lower part of the furnace, 15 feet below the level of the fireplace and on the side next to it. The door is raised by a tackle, and is counterpoised. The discharge is effected by means of a hoe and a rake, attached to handles 12 to 14 feet in length made of inch pipe. The discharging car is of iron, and is half the length of the door. It is rolled to one side of the opening and stopped with the handle of the rake, so as to be exactly opposite the end of the door. The ore, which is black, though not cold, is drawn into it from one side of the charging door until the wagon is half full, it is then rolled to the other side and filled from there. By the time the car is full the red-hot ore appears. The car holds one ton of fully treated ore. One load is drawn every hour from each furnace. The furnace is charged above as soon as the charge is drawn. It is done by the same men who also attend to the fire.

Each furnace requires two men and an aid per shift, so that a single furnace requires six men to treat 24 tons in 24 hours. A double furnace requires only 8 men, who treat 5 tons in 24 hours. To run four furnaces, standing as in Plate VIII, requires 10 men to treat 100 tons in 24 hours. It therefore requires one day's labor to treat 4 tons, 6 tons, or 10 tons in 24 hours, showing a gain of twice and a half on all the labor by increasing the number of furnaces to four. One engine and boiler will do all the work of four furnaces, and three or four cords of wood is sufficient both to burn the ore and to keep up steam to run the blowers.

The draft in the furnace is produced by four Root's blowers, E, F, G, H, placed at the extremity of the condensing-chambers. The bottoms of the condensers U are inclined at an angle of from 15° to 20° . They are joined, as is shown in the drawings, at the top by means of curved iron pipes U'. There are sixteen to each furnace as at present constructed. It is proposed, however, to have four sets of eleven, two sets of ten, and six out of line, making twenty-two in all, or eighteen for each, when the four furnaces are finished. These condensers are 8 feet long, 2 feet 6 inches wide, and 5 feet high at one end and 6 feet at the other. They are set on wooden frames on a cement floor. The first condenser of the series nearest the furnace is set 30 inches, and the last one 37 inches above the ground. Commencing with the next series, the first one farthest from the furnace is 40 inches, and the last one of this series, nearest to the furnace, is 47 inches above the ground. They are made out of three castings, for greater ease of transportation and repair. The top piece is 30 inches in depth all round, is clamped to a projection of the bottom part. The top is made in the shape of a pan, and holds water to the depth of 2 inches. When there is plenty of water it is made to discharge over the top, so as to run down the sides of the condensers, but when water is scarce it simply rests upon the top. At the Manhattan works, which were the first that used the Knox furnace, the condensers are only half the height of those used elsewhere. They have been in constant use for five years, and are nearly worn out, though they may last six months or a year longer. The ore here does not contain much sulphur. These condensers will be replaced by others like those in use here. A very small amount of weak and impure sulphuric acid water commences to condense in the third condenser, but is very abundant in the eighth, and condenses through all the rest. It corrodes the iron-work more or less rapidly. As this action takes place chiefly on the bottom of the condenser, it is cast separate and made several inches thick. As it has been found that the action of the acid water is much less rapid when it is in contact with a small quantity of air, it is allowed to collect for about two inches in the bottom of the last eight condensers, and at this height is discharged from a wooden spout into the mercury trough, and runs to the settling vats M, which are 6 by 10 feet in size and 4 feet deep. A very small amount of mercury is carried off by these streams and collects in this tank. The very small amount so collected shows that the condensation is very nearly perfect. Mercury commences to collect in

the first to the eighth condenser, and is discharged at once into a conduit by a small opening in the bottom of the manhole door. It is collected in the iron pots K, which contain about an inch of water, to prevent the mercury from spattering as it falls into the pot. The iron pipe leading from the trough into the mercury pot is shaped like a goose-neck, so that the acid water runs off above and the mercury collects clear. It is bottled from these pots in the bottling-pot J.

From the end of each set of condensers a wooden box, E', F', G', H', 1500 feet long and 30 inches square, carries the fumes and smoke away from the furnace. The boards of which it is made are clamped against a wooden frame, on the inside by wooden clamps, on the outside so that it can be taken apart at any time. If nails were used they would very quickly corrode, and the flue, if not clamped, would be likely to fall to pieces at any moment. 300 feet from the furnace, on these long flues, there is a chimney, I, which descends about 15 feet high and 4 feet square. This chimney is filled with, large stones, and water is made to flow over them from a pipe connecting with the reservoir S. This reduces the volume of smoke, which, in this way, is made quite cool at this point. 1000 feet from this point the four conduits are united into one, and is continued to the top of the hill, half a mile off. No mercury and no mercurial soot is found in any part of this conduit, or in the flues leading to it. The object of it is to carry away the smoke, which in the winter-time collects in and around the furnace and annoys the men. It is quite common to see the sickly cattle of the neighborhood collect near the end of this conduit and remain there for half a day at a time, so that they have to be driven from it.

The engines, W, which do the work of the two blowers are fifteen horse-power, and are to be used to saw all the wood. It takes $1\frac{1}{2}$ cords of wood for the engines in twenty-four hours. Nothing like fifteen horse-power is required for these blowers, and only four will be required when the six furnaces are built.

All the condensers are cleaned once a week. This is done in the intervals between the charging and discharging by taking off the manhole door and cleaning down the sides with a hoe, but without scraping them. It takes two to three minutes to take out the soot from each condenser. The soot is caught in an iron soot-bucket, which is 2 feet by 3 feet, and 18 inches deep, and is carried on a truck.

The soot from the first eight condensers only is rich enough to

treat; that collected from the others is too poor to work, and is put back into the furnace. The draft into the condenser is so strong that there is no danger that mercurial vapors will escape, if not more than one condenser is open at a time; so that to prevent any possible accident they are opened one by one. After one or two have been cleaned the soot is worked up, and then the others are cleaned. By doing the work in this way times can be selected when the furnace is neither charging or discharging. The quantity of soot which is produced is very variable, and depends entirely upon how thoroughly the condensers are cooled, whether the fire is slow or quick, upon the speed of the blower, and also to some extent upon the changes of the weather, so that the quantity deposited in each condenser will vary at different times. The same is true of the acid water; and it sometimes happens that when the blower is run at the usual speed, and everything else in the furnace is in the normal condition, but the water has given out, that no acid water will be deposited in the first six or eight condensers, the heat, which is usually absorbed by the evaporation of the water, being so great that they remain perfectly dry.

It takes from Monday to Friday to clean out and work up all the soot, which is worked in the usual way with lime on an inclined plane.

On Saturday the conduit and spouts, which get filled with mud, are cleaned, and the flasks are filled with mercury collected during the week. In a charge which gives 150 flasks per week, 40 flasks come from the soot.

The works are so arranged that two furnaces may be run with one blower, or through one set of condensers; and this may become necessary when one of the blowers, or one set of the condensers, have to be repaired. It is more difficult to keep the heat up under such circumstances, and a smaller charge has to be put into each furnace. The diminution of capacity will amount to from four to five car-loads of ore in twenty-four hours. The two furnaces, B and C, will generally treat 50 tons of assorted ore in a day. They have been run without repairs since January, 1874, and have produced from 600 to 900 flasks a month, the variation depending upon the richness of the ore.

It is the intention to make the trial of distilling all the soot in a retort, P. The retort is built, but the trial had not at the time of my visit been made.

At the Manhattan works the soot is worked up in a retort to

which a Liebig condenser, like Q, 10 feet long, is attached. The condensing pipe is large enough to hold a barrel of water at one time.

The experiment is being made here of working the soot mechanically. It is mixed with lime and is put into an iron rocker, which has several motions, and in which a rake works backwards and forwards. A very large part of the mercury in the soot is collected in this way by machine labor without necessarily having any one to tend it. The rocker is run by the steam-engine of the works. This machine is not yet perfected. Working as it did at the time of my visit, some of the mercury separated is afterwards flowered. This is a serious imperfection, but it is expected will be shortly overcome.

The best men in the works at Knoxville are always selected for the Knox furnace. They work twelve hours, and are paid \$40 for 30 days and board. If the men have families and occupy the company's cottages they are allowed \$20, as a commutation for board, but they pay \$7½ per month for rent.

California Works.

The California Quicksilver Works also use the Knox furnace. They treat their own ores and produce 26 flasks of 76½ pounds of mercury a week. All the ore passes over a coarse screen, so as to separate the large pieces from the fine and small, which are separated by other screens in the same shute. The larger pieces are broken by hand. The fine ore which is rich enough is made into adobes. One man mixes his dirt and makes 900 a day. The poor fine ore is dressed by hand gigs, and six men treat 10 tons, and reduce it to one-eighth of its former capacity. The enriched ore contains about five per cent of mercury, but a considerable quantity of cinnabar is lost in the tailings, and it is doubtful whether the dressed ore pays for the labor expended upon it.

The men are paid \$40 and board, which equals \$2 a day.

The attempt was made here to treat the soot in the arched chamber Z' opposite the fireplace, but the gases of the furnace contained so much free oxygen at this point, that the result was the formation of a large quantity of sulphate of mercury, and the attempt was abandoned. The works have been managed with so little care that the condensing-chambers, which have been used only 18 months, are so corroded that they will have to be taken out. Long stalactites of acid sulphate of iron are hanging from them in every direction, and the walls in some cases have been entirely eaten through, or are so

thin that they could be easily pushed through with the finger. It is the intention to replace the last eight condensers by brick chambers, 8 by 10, and $4\frac{1}{2}$ feet high, with three partitions. When the iron condensers are in good repair the soot is found in from the third to the sixth, but now they are leaking it is found in from the first to the third. The soot is drawn every week from the first six condensers; beyond the sixth they are cleaned only once in three months. The soot collected in the first six condensers is about six ordinary sugar barrels per week. The quantity depends upon the sulphur in the ore, its dampness, and other causes.

Good oak wood is $\$4\frac{1}{2}$ per cord. About two cords in twenty-four hours are burned in the furnace. Brushwood is not as cheap as other wood here, and is consequently not used. There are five men in twenty-four hours about the furnace. At night the fireman and engineer alone run it.

In discharging the furnace the engineer fills the wagon while the furnaceman draws the charge down. In the daytime there is a superintendent of the work, beside one man making adobes. The miners are required to deliver the ore broken and sorted. There are 100 men working in the mines. The miners are paid $\$45$ a month. The works have been run constantly for 18 months without repairs, and have not stopped more than three weeks during the whole of this time for any cause.

The first Knox furnaces constructed cost between $\$35,000$ and $\$40,000$ each. They were built when wages were high, and labor was difficult to get. The furnaces since constructed have cost about $\$25,000$ each. There are 170,000 brick in the furnace beside the stone, but nearly half the cost of construction is for iron-work.

Below is a statement of the cost, at the Redington mine, of treating the ore in the modified Idria furnace and the Knox furnace.

Cost per ton of reducing ore in the modified Idria furnaces, Nos. 1 and 2, at the Redington mine, Napa County, California, in 1874, taking one week's run, both furnaces:

5½ cords wood, at \$5, ...	\$24 50
36 days. Furnace foreman and his assistant, ...	86 00
20 " Laborers charging furnace, ...	38 60
12 " Laborers discharging furnace, ...	23 15
8 " Laborers working soot, ...	14 55
8 " Fireman, ...	14 55
9000 adobes, at \$5 per thousand, ...	45 00
Total charge of 200 tons ore in these two furnaces cost	\$249 35
Average cost per ton for reduction, ...	1 25

Cost per ton of reducing ore in the Knox furnace at the Redington mine, furnaces Nos. 3 and 4, taking one week's run of both furnaces :

42 days' labor, engineer, fireman, soot men, etc., . . .	\$81 06
17½ cords wood, at \$5, ...	87 50
1 gallon oil for lamps, ...	75
1 gallon lard oil for engine, ...	1 20
Total cost of one week's run, ...	\$170 51
Average cost per day for reducing 50 tons, . . .	24 36
Average cost per ton, ...	50

The difference between \$1.25, which is the cost of treatment in the modified Idria furnace, and \$0.50 the cost of treatment in the Knox furnace, is sufficiently great not only to warrant the use of much poorer ore in the latter furnace, but to call seriously into discussion whether it is not worth while to abandon the old style of furnaces altogether.

Below is given an estimate of the principal items of expense of building *one* Knox & Osborn quicksilver furnace, in October, 1874:

50 to 75 M red brick.	
12 M fire-brick.	
Stone for foundation, walls, etc.	
1 cast-iron lintel, weight, ...	3000 lbs.
1 cast-iron draw-door frame, weight, ...	650 "
1 set draw plates, cast iron, weight, ...	3500 "
18 cast-iron condensers, complete, weight each, ...	6500 "
1 fire-door and frame, weight, ...	650 "
1 flue-chamber plate and door, weight, ...	1000 "
6 braces, weight, ...	3000 "
1 blower-box, weight, ...	2500 "
2 pots, etc., weight, ...	500 "
1 set grate-bars, weight, ...	1200 "
1 blower, ...	\$500
Blower pipes, ...	\$50
1 retort and condenser, ...	\$500
1000 feet wooden flues, cost per running foot, ...	\$1
1 engine, with pulleys and shafting, 8 x 12 cylinder.	
2 boilers (12 x 3).	
35 square timbers, 12 inches by 12 inches, and 21 feet long.	
60 round iron rods, 1½ inch diameter, 23 feet long, 10-inch washers on both ends.	
2 cars, railroad tracks, etc.	

It takes six or eight masons, with their helpers, between three and four months, to build one of these furnaces. The cost might be made less by making more than one-half of the condensers of wood. They might answer even nearer the furnace, if there was a certainty of always having a large supply of water, so that they could be kept constantly wet.

Cost of labor would be about	\$5,000
Cost of building the furnaces 3 and 4, and condensers now in use, . .	60,000

Below is given Knox & Osborn's estimated cost of a quicksilver furnace, with a capacity of 75 tons, or to work 24 tons every twenty-four hours :

Cast iron in furnaces, 17,000 lbs., at 6 cts. per lb., . . .	\$1,020 00
Cast iron in condensers, 91,600 lbs., at 6 cts. per lb., . . .	5,496 00
Work, planing and fitting, ...	\$90 00
1 conical charging car, ...	150 00
1 discharging car, ...	125 00
1 Knox patent suction blower, ...	400 00
2 boxes borings to caulk condensers, ...	10 00
3 iron kettles, 120 gallons each, ...	100 00
Forging bolt ends, and nuts and screwing, ...	70 00
	945 00
Gross amount of foundry bill, ...	\$7,461 00
20,000 feet lumber, at \$20 per M, ...	400 00
80,000 red brick, at \$10 per M, ...	800 00
7000 firebrick, at \$60 per M, ...	420 00
4000 lbs. wrought iron, at \$5 per M, ...	200 00
1 set blocks and fall (watch tackle) 6 inches, ...	10 00
2 iron sheaves, 1½ x 6 inches, ...	5 00
4 iron side pulleys, ...	2 00
40 feet chain, ½-inch wire, ...	2 00
10 kegs nails and spikes, at \$4.50 per keg, ...	45 00
	1,884 00
Labor, erecting furnace, ...	\$2,000 00
Boiler and engine, four horse-power, ...	800 00
	\$12,145 00

In this estimate nothing is included for grading site, drayage, freight, hauling brick, sand, clay, rock, and timber, to the furnace; nor for the sheds to cover the structures. As different sized furnaces would require about the same amount, as an approximation, we may say, that \$3000 would cover an extreme case, and \$1500 would suffice for a very favorable one. In a position where water for a four horse-power can be had, a saving in the first cost is effected, and a greater saving in the current expenses of running.

There are two sizes of this furnace, a half size, or 12-ton furnace, which easily treats 15 tons, and has, when crowded, worked 17 tons.

The full size, or 24-ton furnace, crowded in the same way, will work 30 to 34 tons.

The cost of the half size furnace is about	\$9,000
The cost of the three-quarter size furnace is about	14,000

Both these sizes have been built within the year 1874, and they are giving perfect satisfaction.

The following is the estimated cost of running or operating the Knox & Osborn furnace, at the Manhattan works, per day of twenty-four hours, when run by steam power :

For an average ore for 24 hours, $1\frac{1}{4}$ cords of wood (oak), at \$4.50 per cord,*	\$5 63
2 men on each watch of twelve hours, or 4 men, \$50 per month, and board, \$2.53 per day,	10 12
Oil for light and engine,	50
Cost per day of reducing 24 tons of ore,	\$16 25
Cost per ton,	67 $\frac{2}{17}$

With regard to these systems of working it may be said that the advantage of the retort system is its economy of installation. It does not appear that there is any gain in yield, though this is claimed for it, while the expenses for fuel and labor are necessarily a maximum, as the amount which can be treated at any given time must be considered as a minimum. The cost of repair is also a maximum, since the iron of the retort is rapidly attacked by the sulphur of the ore, which destroys them, so that a larger number of them must always be kept on hand. The danger of accidents from salivation is at a maximum, even when the precaution of using a blower, as at the Missouri mine, is taken, and there seems to be no good reason why such furnaces should not go out of use altogether.

There is evidently a limit beyond which the speed of the blowers, which are so characteristic of California practice, cannot be increased. Not only is a large surface necessary to a perfect condensation, but a certain amount of time is quite as indispensable to cool the volatilized material, in order to have it condense. If, therefore, the condensing surface be a maximum, but the velocity of the current too great, it is evident that there will be a loss of mercury, which will be exhausted out of the condensers by the rapidity of the current. The proper speed of the blower will vary at different times, and with the obstruction caused to the passage of the air, by the kind of condensers used, and by the character of the ore charged in the furnace. It is evident that in a given furnace, the ore may be charged so fine, that it will pack in such a way, that no speed of the blower will draw the furnace's gases through it, or so large that a few revolutions per minute will be all that will be required. Between these two extremes there is a mean, which can only be determined by the judgment of the person in charge of the furnace, and it is often pre-

* Of this one cord would fire the furnace, one-quarter the boiler. Ores rich in sulphur will not require over one-half cord of wood in twenty-four hours.

cisely this judgment and skill, which may or may not have been acquired by long experience with a process, which makes an inferior process give good results in one place, and the want of it which makes a good process fail in another. Such examples occur throughout the whole range of metallurgical industry, and not in the metallurgy of mercury only.

The objections to masonry condensers are generally the penetrating power of the mercury, which is so great that it not only impregnates the vertical stone or brick walls of the chambers, but infiltrates into the ground to such an extent that on taking up the foundations of some old furnaces at New Almaden, about the year 1863, mercury was found to have penetrated through the foundation, and the clay beneath it to the bed rock a depth of 25 to 30 feet, and over 2000 flasks were recovered in a single year from the foundations of two furnaces. This loss is now prevented by building the condensing chambers upon double arches, into which plates of iron are built so as to cut off the flow of mercury, and turn it inwards towards an iron basin into which it may be seen to fall in intermittent streams every few minutes. At the time of my visit to New Almaden a large shaft had been dug beside one of the furnaces, and at the depth of 30 feet, it was still profitable to wash the dirt in order to collect the mercury from it. In 1874 sufficient mercury was obtained from the brick ore-chamber, and three condensing-chambers of a furnace, and from the dirt around the structure, to more than pay for the new shaft furnace and condensers. For the construction of condensers bricks, though porous, are much preferable to and I think less porous than the sandstone used in the old Idria furnaces at the Redington Works. Whenever repairs in the condensers at Knoxville have been made with brick, they have stood while the sandstone next to the bricks has been worn away. It is evident that what is required is some substance that will be impervious to mercury. Bricks, however, are not so. Every brick or piece of sandstone taken out of a condenser must be considered and treated as a very rich ore of mercury, for whenever broken myriads of globules of metallic mercury are seen scattered through it. Iron is better than brick, in that it does not absorb mercury, but it is rapidly corroded by the sulphuric acid which condenses. Wood is much cheaper, but cannot be used near the furnace on account of the heat. At a certain distance from it, it is more or less rapidly acted on by the condensing sulphuric acid. It seems perfectly practicable to make such a combination of wood and glass that will stand at a

certain distance from the fireplace, and by placing the condensers made of brick near the furnace, and cutting them up into smaller structures so that they shall not retain the heat, or substituting iron condensers with water cooling arrangements, for them to arrange a good condensing apparatus. By using, for instance, the Knox condensers together with the wood and glass arrangement recently patented at Almaden, it would seem that a much better condenser would be made than any now in use.* In any case a few large compartments are not so effective as the same volume distributed among a large number of small ones. What is required to effect a perfect condensation is surface more than volume, and more especially sudden and frequent changes of the direction of the current of volatilized material. With a furnace having only a natural draft this was impracticable, but with a furnace working by an exhaust fan, where obstacles can be introduced within certain limits, it is only necessary to increase the speed of the fan to get the necessary draft. There is, however, evidently a limit of obstruction which cannot be overstepped.

There seems to be a very decided advantage in using an artificial fuel when it can be had; European experience has pronounced decidedly in favor of it. At New Almaden a series of experiments were made during the years 1873-4 with coke and charcoal, and a mixture of both, but at the time of my visit no definite conclusion had been arrived at. It would seem even advantageous under certain circumstances to mix a certain amount of fuel with the ore, especially when large amounts of fine ore not made into adobes must be charged. It is evident that the fuel which contains the least amount of moisture, if it is not friable, will prevent the formation of a certain quantity of soot, and as artificial fuels generally contain less moisture than natural ones, there would probably be less acid condensed if they were used. There are places, however, where the cost of making the artificial fuel would more than counterbalance the advantage gained.

Every system in use, and some which are not, have their supporters. When the date of the discovery of these deposits in California is taken into consideration, it must be confessed that more

* While this paper is going through the press, Mr. C. E. Livermore, of the Redington mine, writes that they have commenced to use six or eight wooden condensers to each furnace. They are made of seasoned red wood $1\frac{1}{4}$ inches thick, and of the same size and shape as the iron ones. They are found to last at least equally as well, and are far cheaper.

rapid strides have been made in the metallurgy of quicksilver there than in Europe. There is, however, much to be done. So little is known of what is done, and the prices of the metal have been subjected to such great fluctuations, that except in the case of the wealthy companies, there has been but little encouragement to experiment. The price of quicksilver in San Francisco in August, 1874, was \$1.75 per pound. It is now 75 cents, and has been in former years as low as 35 cents. Such prices as these, if they should rule again, would compel almost all the small works to stop. The general feeling is that every advantage must be taken of the present. Under such circumstances the small works must wait to benefit by the experiments and experience of the larger ones, if they are not entirely ruined by the fluctuations in value before they have the opportunity.

In conclusion, I beg to express my thanks to Messrs. C. E. Livermore and J. W. Hall, of the Redington mine, and to Mr. R. F. Knox, of the firm of Knox & Osborn, in San Francisco, who have furnished me photographs, drawings, and a large amount of information before and since my return from California, and to the managers of the works generally who were always ready to facilitate the object of my visit.

Fig. 3.

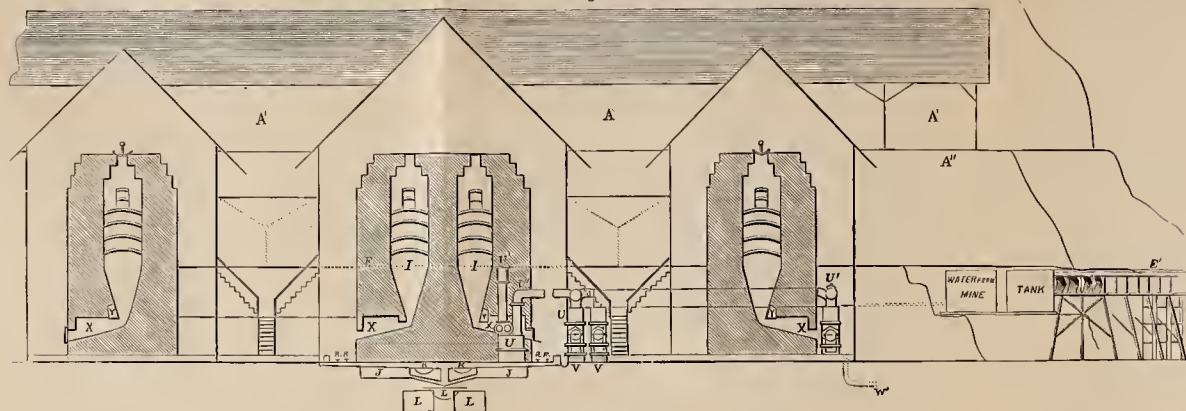


Fig. 4.

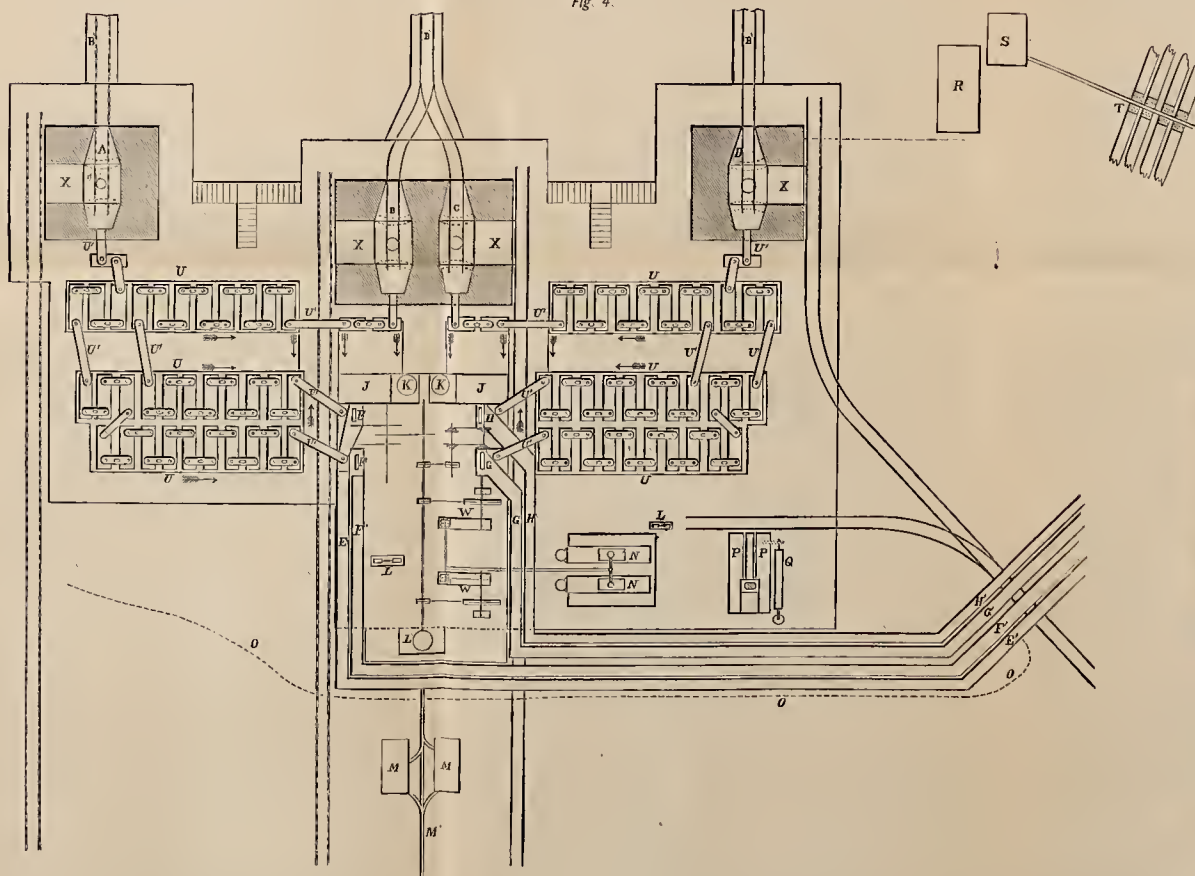


Fig. 1.

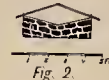
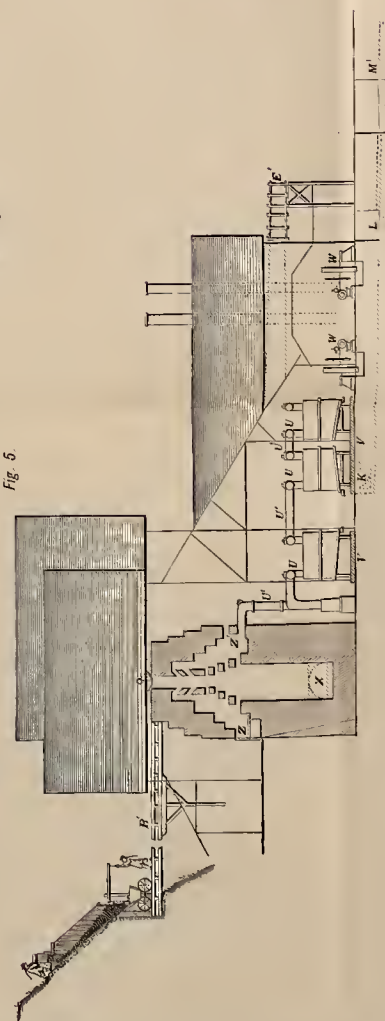


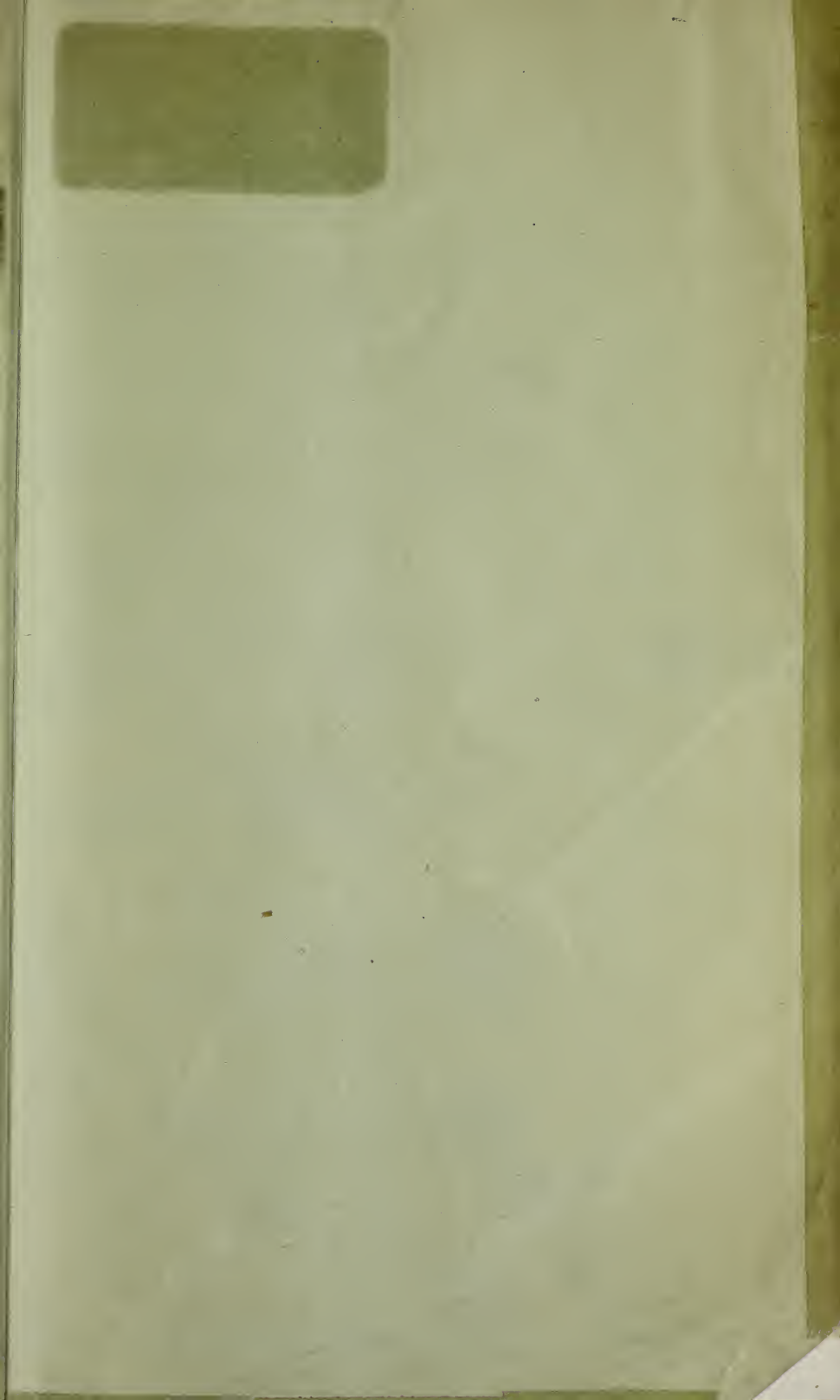
Fig. 2.

Fig. 5.



- A—Furnace No. 5.
 - A'—Ore House.
 - A''—Dump Heaps.
 - B—Furnace No. 3.
 - B'—Bridge.
 - C—Furnace No. 4.
 - D—Furnace No. 6.
 - E—Blower No. 3.
 - E'—Wooden Flue No. 3.
 - F—Blower No. 5.
 - F'—Wooden Flue No. 5.
 - G—Blower No. 6.
 - G'—Wooden Flue No. 6.
 - H—Blower No. 4.
 - H'—Wooden Flue No. 4.
 - K—Collecting Pot.
 - I—Fire level in the Furnace.
 - J—Bottling Pit.
 - L—Steam Pump.
 - L'—Pot and Pit for Tailings.
 - M—Settling Tanks.
 - M'—Drain for the Tanks M.
 - N—Steam Boilers.
 - O—Road around the Furnaces.
 - P—Retort for working the Soot.
 - Q—Road around the Furnace.
 - R—Water-tank for the main Condensors.
 - S—Water-tank for the Flue Chimney.
 - T—Flue Chimney and Shower of Water.
 - U—Iron Condensors.
 - U'—Iron pipes connecting furnace and condensors.
 - V—Floor in cement.
 - W—Steam Engine.
 - X—Draw for the treated ore.
 - Y—Iron box for heating the air.
- The arrows show the flow of the mercury.

Scale of Figs. 3, 4, and 5, 20 feet to the inch



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